UNCLASSIFIED

JADS JT&E

Verification and Validation of the JADS End-to-End Test- The Final Chapter

By: Gary Marchand

December 1999

Distribution A- Approved for public release; distribution is unlimited.

Joint Advanced Distributed Simulation
Joint Test Force
2050A 2nd St. SE
Kirtland Air Force Base, New Mexico 87117-5522

UNCLASSIFIED

VERIFICATION AND VALIDATION OF THE JADS END-TO-END TEST
THE FINAL CHAPTER

Gary Marchand, SAIC
marchand@jads.kirtland.af.mil
(505) 845-1165
JADS JTF
2050A 2nd St. SE
KAFB NM 87117-5522
http://www.jads.abq.com

ABSTRACT

The End-To-End (ETE) Test, conducted under the auspices of the Department of Defense (DoD) Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E), developed a synthetic test environment that can be used for future testing, training and doctrinal development. This synthetic environment was used to conduct developmental and operational testing of the Joint Surveillance Target Attack Radar System (Joint STARS).

The final chapter of the ETE Test was the Phase 4 advanced distributed simulation (ADS)-enhanced operational test (OT). Phase 4 consisted of three flights of the Joint STARS E-8C over Fort Hood, Texas. During the flights, the aircraft conducted radar surveillance of a battlefield consisting of Fort Hood and its environs and eastern Iraq. The synthetic environment, represented on the radar screens, consisted of 10,000 virtual entities involved in a battle in Iraq and numerous real entities located at Fort Hood. The virtual battlefield was generated by the U.S. Army Training and Doctrine Command Analysis Center (TRAC), White Sands Missile Range (WSMR), New Mexico, using Janus. Radar images observed on the aircraft consisted of real, virtual, and mixed images displayed simultaneously on the operator workstations. All radar data were transmitted to Army ground stations and further processed by the Army's All Source Analysis System (ASAS). Targets were chosen based upon the radar data and sent to Fort Sill, Oklahoma, where virtual Army Tactical Missile System (ATACMS) missiles were fired back into the Janus battlefield. The results of these fire missions were than observed by the radar and presented to the ground stations.

Prior to conducting the Phase 4 OT, the simulations and synthetic environment were verified and validated using the DoD Recommended Practices Guide and the Distributed Interactive Simulation (DIS) Nine Step Process. This paper will discuss the difficulty involved in verifying and validating a complex synthetic environment involving satellite transmission of data and the need to complete some steps of the verification and validation (V&V) during the actual testing because of the inability to replicate the test environment in the laboratory. In addition, it will discuss the value of V&V during the conduct of the test as a measure of the synthetic environment's test readiness. Conducting V&V activities prior to a test demonstrates to the tester that the synthetic environment can meet the test requirements. The repeating of certain V&V activities during the test confirms to the tester that the synthetic environment is functioning as expected and ready to meet the test requirements.

1. End-To-End Test Overview

The End-To-End (ETE) Test was one of the three tests conducted under the auspices of the Department of Defense (DoD) Joint Advanced Distributed Simulation (JADS) Joint Test and Evaluation (JT&E). JADS was chartered to investigate the utility of advanced distributed simulation (ADS) technologies for the support of developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). The program is Air Force led with Army and Navy participation. Science Applications International Corporation (SAIC) provided contracted technical support to the ETE Test.

The ETE Test was designed to evaluate the utility of ADS to support the testing of command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems. It conducted its test and evaluation (T&E) utility evaluation in an ADS-enhanced test environment using the Joint Surveillance Target

Attack Radar System (Joint STARS) as the system under test immersed in a representative C4ISR environment. The ETE Test also evaluated the capability of the JADS Test Control and Analysis Center to control a distributed test of this type and to remotely monitor and analyze test results.

The ETE Test used distributed interactive simulation (DIS) to assemble a synthetic environment (SE) for testing C4ISR systems. The intent was to provide a complete, robust set of interfaces from sensor to weapon system, including the additional intermediate nodes that would be found in a tactical engagement. The test traced a thread of the complete battlefield process from target detection to target assignment and engagement at corps level using ADS. It allowed the tester to evaluate the entire thread, or the individual contribution of any of the parts, and to evaluate what effects an operationally realistic environment had on the system under test (SUT).

The test concept was to use ADS to supplement the operational environment experienced by the E-8C and light ground station module (LGSM) operators by adding additional entities to the battlefield seen by Joint STARS.

Also, by adding additional elements of the command, control, communications, computers and intelligence (C4I) systems that Joint STARS interacts with and a weapon system to engage targets, the test team could evaluate a thread of the complete battlefield environment from target detection to target assignment and engagement.

This was accomplished by adding approximately ten thousand simulated targets to the live targets seen by the radar on board the E-8C aircraft. Consequently, a battle array approximating the major systems present in the area of interest was presented to the operators both in the air and on the ground. A network was then constructed with nodes representing appropriate C4I and weapon systems that provided a more robust cross section of players for interaction with the E-8C and LGSM radar surveillance operators.

Several components were required to create the ADS-enhanced operational environment used in the ETE Test. In addition to Joint STARS, the ETE Test required a simulation capable of generating thousands of entities representing the rear elements of a threat force. For this purpose, the ETE Test team selected the U.S. Army's Janus simulation.

Also, a simulation of the Joint STARS radar, called Virtual Surveillance Target Attack Radar System (VSTARS), that simulated both moving target indicator radar and synthetic aperture radar was developed to insert the simulated targets into the radar stream on board the E-8C while it was flying a live mission.

The target data were sent to the aircraft for processing by VSTARS using satellite transmission. More will be said about this later.

Other capabilities used to support the test included simulations or subsets of the Army's artillery command and control process and a simulation of the Army Tactical Missile System.

The ETE Test consisted of four phases. Phase 1 developed or modified the components that allowed the mix of live and simulated targets at an E-8C operator's console and LGSM operator's console. Phase 2 evaluated the utility of ADS to support DT&E and early OT&E of a C4ISR system in a laboratory environment. Phase 3 moved components of VSTARS onto the E-8C aircraft, ensured that the components functioned properly, and checked that the synthetic environment properly interacted with the aircraft and the actual LGSM. Phase 4 evaluated the ability to perform T&E in a synthetically enhanced operational environment using typical operators.

More detailed information on the ETE Test can be found on the JADS web site.

2. ETE Test Verification, Validation and Accreditation Methodology

Since JADS is a DoD-sponsored joint test, the overall guide for the V&V of the JADS End-to-End (ETE) Test was the *Department of Defense Verification, Validation and Accreditation Recommended Practices Guide (DoD VV&A RPG*). The JADS ETE Test utilized the Institute of Electrical and Electronics Engineers Standard 1278 for

Distributed Interactive Simulation to develop its ADS-enhanced test environment. The DoD VV&A RPG advocated the use of the DIS Nine Step VV&A Process for the VV&A of the DIS enhanced test environment.

The DIS Nine Step VV&A Process was developed with the knowledge that it must be tailored to each individual use. The tailoring of the VV&A process resulted in the JADS ETE Test VV&A process model shown in Figure 1.

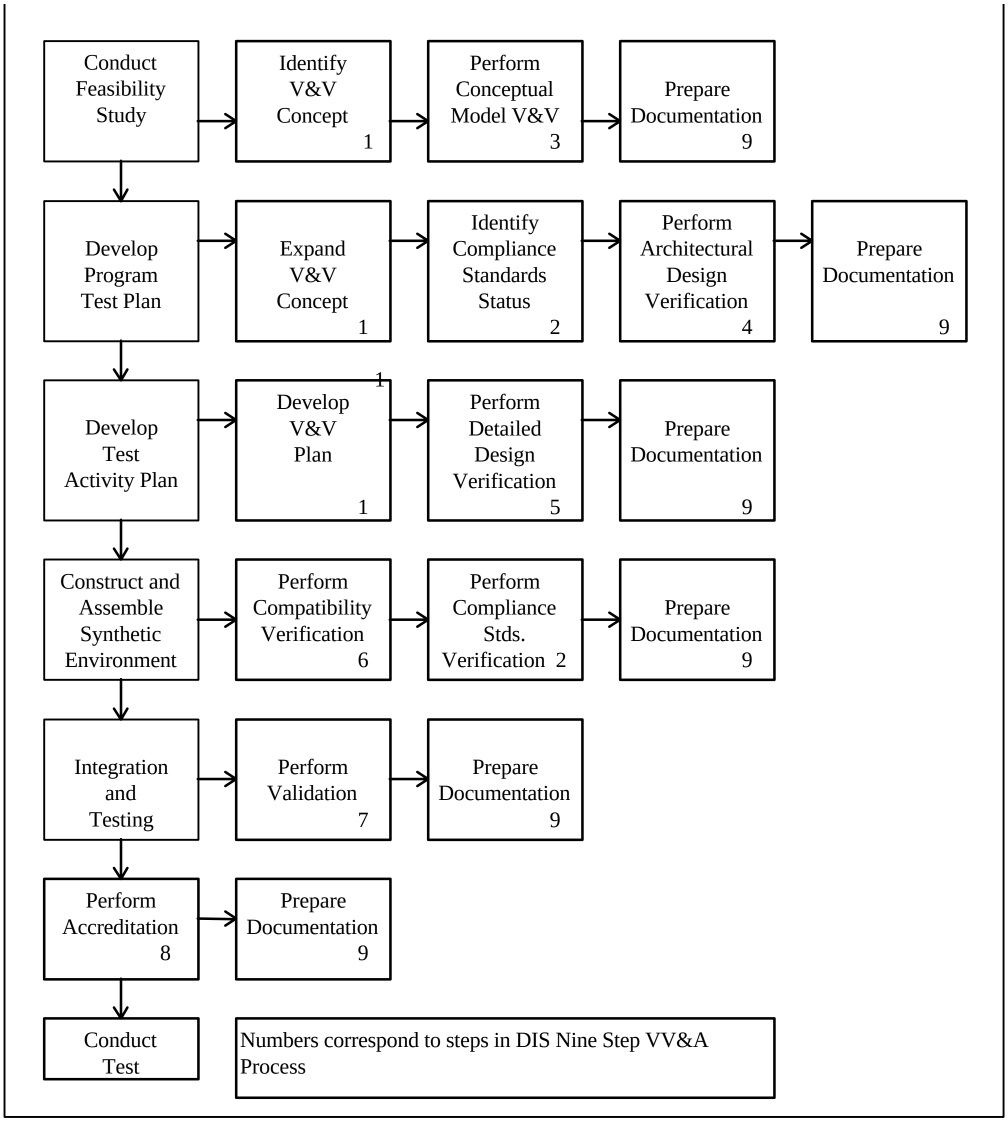


Figure 1. JADS ETE Test VV&A Process Model

In the JADS ETE Test VV&A Process Model, test events, which consist of the planning, constructing and assembling the SE, integrating and testing the SE, accrediting the SE, and conducting the test all proceed on the left side from top to bottom. The V&V events, to include documentation, proceed to the right for each major test event.

The major change from the DIS Nine Step VV&A Process is the inclusion of the ADS-enhanced test environment accreditation as a part of the test process resulting in an eight step V&V process. Accreditation is not a part of the DIS exercise process in the DIS VV&A Process Model. Instead, it is shown as a part of the VV&A process, and by implication is not something that is required prior to the conduct of the DIS exercise. When ADS is used in support of operational and developmental testing, accreditation of the models and simulations (M&S) is a management function and is a mandatory part of the test process.

The V&V of the ETE Test ADS-enhanced environment were based upon the functional requirements and acceptability criteria taken from the test plans and other documents that describe the test environment. The V&V agent developed the V&V plan by identifying the tasks required to satisfy those requirements and acceptability criteria in a manner that matched and complemented the test activity plan, test requirements, component requirements, available resources, and timelines.

As can be seen from the process model, during the feasibility study the V&V concept was identified and the conceptual model of the ETE Test was validated.

During the development of the program test plan, which corresponded with Phase 1 of the ETE Test, the V&V concept was expanded and the compliance status of the legacy simulations was checked.

The remainder of the V&V process was completed during Phase 2 of the ETE Test, which culminated with the operational testing of Joint STARS in a laboratory environment. The results of this V&V were presented last year at this conference in a paper entitled *ETE Update - ADS Testing of C4ISR Systems.*

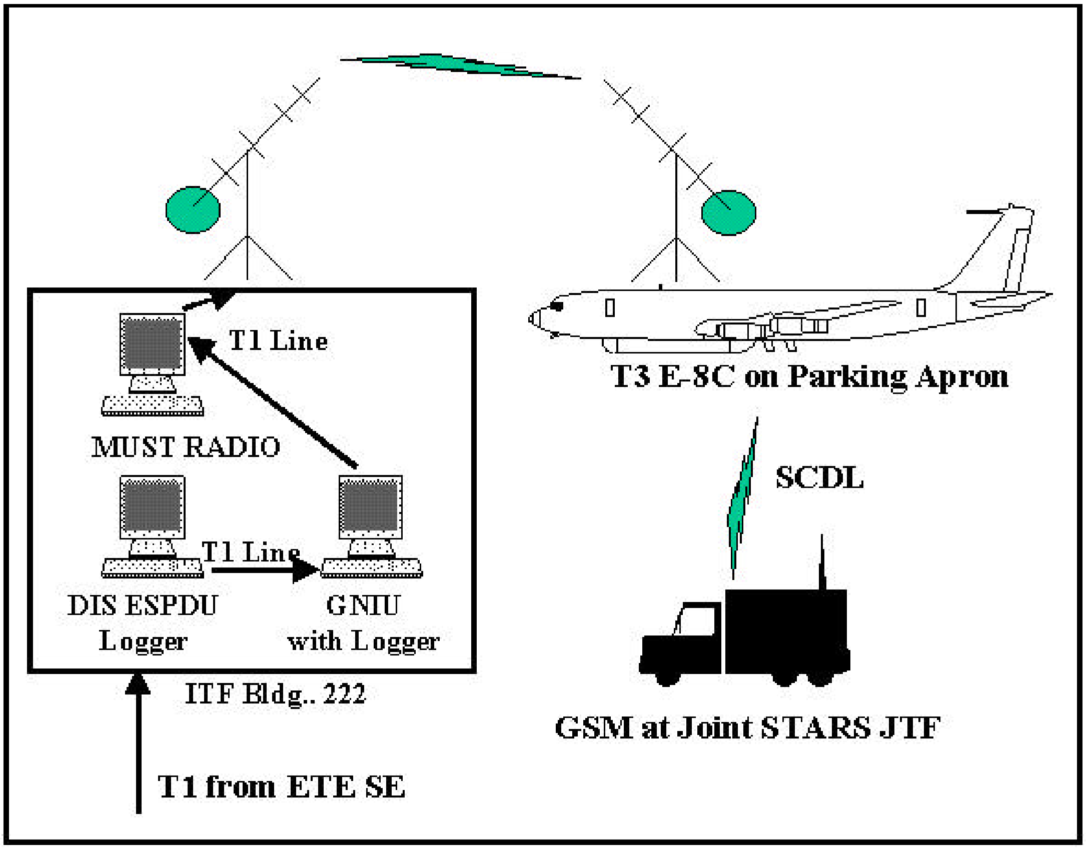
3. Almost the Final Chapter

The ETE Test team was blessed in that we got to V&V the environment twice. Phase 3 of the test was designed to move the radar simulation out of the lab and integrate it into the radar subsystem on board the Joint STARS E-8C aircraft. The DIS-derived data required by the radar simulation would be provided using satellite transmission to the aircraft while it was flying a mission. Details are available on the JADS web site.

The *Department of Defense Verification, Validation and Accreditation Recommended Practices Guide* gives six benefits of VV&A. Obviously, the first two, increased confidence in modeling and simulation (M&S) use and reduced risk of M&S use, apply in this instance because not only was this a major modification of the previously accredited environment, but there were concerns about whether we could even make it work. Phase 4 of the ETE Test called for several test flights using an expensive and over-committed test aircraft that would require a high level of confidence before the test flights occurred.

However, problems were encountered in conducting the Phase 3 V&V. The first and foremost problem encountered was that we could not create the test environment without flying the aircraft. This problem was compounded by the fact that nobody was going to let us use the aircraft just for V&V.

The testing and V&V configuration, shown in Figure 2, were as close to flight conditions as it was possible to duplicate. System integration tests and V&V were conducted using line-of-sight transmission and, when satellite time was available, satellite transmission.



ESPDU = entity state protocol data unit
GNIU = ground network interface unit
SCDL = surveillance control data link
T1 = digital carrier used to transmit a formatted digital signal at 1.544 megabits per second
GSM = ground station module
JTF = joint test force

Figure 2. System Integration Test and V&V Configuration

Although this environment was very close to the test environment, we knew that it was not close enough. When the aircraft took off, the environment became dynamic. As the aircraft proceeded toward Fort Hood, Texas, and the entity starting positions were loaded in the database, the relationship of the aircraft was constantly changing with respect to the satellite.

In addition, once the aircraft arrived on station, it flew an orbit that allowed it to keep the mission area within the radar field of view. As the aircraft banks during the turn at each end of the orbit, the orientation of the aircraft's satellite antenna changes with respect to the satellite. When the aircraft banks toward the satellite, reception should improve, and when it banks away, reception should worsen. Pretest calculations indicated that there was a possibility that data would be lost during the turn that banked the antenna away from the satellite.

We did, however, V&V the performance of the radar simulation on board the aircraft and determined that with one major exception, it did not affect the performance of the other subsystems on the aircraft.

Before discussing this exception, it should be pointed out that at this stage the V&V conducted to date did give the test team a high degree of confidence that the SE would function under the test conditions.

The exception was one that we had known about all along and had planned from the beginning to verify during the test flights. One of the requirements for the radar simulation was that it did not affect the performance of the actual radar during its operation. This can only be determined by measuring the performance of the radar during a mission using instrumented vehicles, ground reflectors, and ground emitters. This was scheduled to be done during the second mission, and the data would be analyzed by the Joint STARS Joint Test Force (JTF).

The scheduled system integration tests required by the Joint STARS JTF and the V&V tasks were performed on Saturday, 13 March. The first scheduled flight was on 19 March. During the V&V, a problem with the satellite transmission was detected. Fortunately, this problem could be corrected using laboratory facilities, and the V&V of the satellite transmission took place on 17 March.

The scheduling of the test flights could not be moved because the test aircraft was scheduled for a major reconfiguration on 3 April.

As a result of the scheduling constraints and the fact that the V&V was incomplete, the accreditation authority decided to proceed with the flights without accreditation. The V&V conducted to date provided a reasonable assurance that the environment would function well enough to provide valid test data. The data collected during the flights would be used to complete the V&V and the results would be presented to the accreditation board. They would then say whether we were wise and sage, or just plain desperate.

4. Phase 4 Verification and Validation – The Final Chapter

The Phase 4 test flights occurred from 19 - 31 March and were conducted by the Joint STARS JTF in support of JADS using the E-8C test aircraft designated as T3. There were a total of three flights flown with the entire ETE Test SE activated during each flight. Results of the Phase 4 operational test (OT) may be found on the JADS web site.

During the flights, we needed to advise the Joint STARS JTF that the system was healthy and working properly upon arrival at the mission area. We also needed to advise them if the system went down at any time during the mission. Like all Joint STARS missions, our flights carried personnel who could perform other tests if our systems did not work.

It was decided that the best way to determine if the system was working properly was to perform certain critical V&V checks. These V&V steps would look primarily at the functions used during the flight and the operational testing.

During the flight to the mission area, the JTF would verify that the live radar appeared to be operating properly. Once this was completed, we would initiate the radar simulation and verify that it was operating properly. As a part of initiating the radar simulation, we would also establish and check out the satellite communications.

When all was ready, we would then proceed to load the radar simulation database with the start-up location of all of the entities using the satellite link. The status of the database could be monitored and once it was loaded, provided we were on station, the scenario would be started. Scenario data would be provided to the radar simulation for the remainder of the flight using the satellite link.

All data transmitted over the satellite link were logged at both the source and the aircraft. These logs were used post-test to determine data dropout and latency. These data were then compared to the flight logs and loss during turns was detected. The loss was small enough, however, that it did not affect the validity of the radar images. This completed that portion of the V&V.

The time over the mission area was divided into three segments. The first segment consisted of virtual radar only with only the 10,000 simulated entities appearing on the radar screen. During this segment, a subset of the V&V activities deemed critical for the virtual radar was performed. At the same time, operational test data on the Joint STARS were collected. The validity of these data was determined post-test based upon the results of the V&V performed.

The second segment consisted of a virtual radar area and an actual or live radar area. During the 25 March mission, instrumented vehicles, reflectors, and emitters were present in this area, and data were collected on the performance of the radar while the radar simulation was operating. Subsequent analysis showed that the radar simulation did not impact the radar on the aircraft. In addition, during this segment, V&V activities were performed at the same time that OT data were being collected.

The third segment consisted of three areas: the live and virtual radar areas previously discussed and a mixed area. In the mixed radar area, both real radar returns and simulated radar returns were mixed resulting in a very realistic and cluttered radar image. Again, V&V activities were performed at the same time that OT data were being collected.

Results of the Phase 3 & 4 V&V are also available on the JADS web site.

5. VV&A Lessons Learned

Several lessons were learned, or relearned, during the VV&A of the End-To-End Test.

The primary role of V&V during the conduct of an ADS-enhanced test is to reduce risk and meet policy requirements. The tester must have a high degree of confidence that the ADS-enhanced test environment will work prior to conducting costly and resource intensive test events. V&V can provide that high degree of confidence. The greater the risk, the more V&V are required. Low risk test environments require only enough V&V to meet policy requirements.

Requirements must exist before any V&V can be conducted. This is all right because a federation needs requirements before it can be developed. If the developer of the federation cannot state what it is supposed to do, it is extremely difficult to build and V&V the federation. This holds true for both the federation overall and the individual federates that comprise the federation. The level of V&V should match the level of sophistication of the requirements and their associated acceptability criteria. When the requirements and acceptability criteria are conceptual in nature, only conceptual V&V can be conducted. As the requirements become more detailed and refined, the V&V should become more detailed and refined.

Involve the accreditation folks early in the process. They are responsible for developing the acceptability criteria based upon the test requirements. The V&V plan, with its associated cost estimate, cannot be developed until the acceptability criteria are agreed upon between the test manager and the accreditation authority.

Acceptability criteria are specifications the federates and federation must meet. V&V are the testing required to determine how well they meet specifications. Requirements must exist before acceptability criteria may be developed. Acceptability criteria are a measure of the risk the accreditation authority is willing to accept prior to conducting the test.

If a V&V activity does not reduce risk it is probably not needed. The developer wants to know how well the federates and federation meet the requirements in order to proceed with minimal risk. Risk reduction is important because there are always a limited number of test events, either because of money, time, or limited availability of test assets. Therefore, the tester wants to maximize the value received from a test event and minimize the chance of something going wrong that would prevent collecting valid SUT data. Conducting V&V does this.

V&V are affordable, provided they are integrated into federates and federation testing. The developer's first thought should be what do I want my federation to do. His second thought should be how am I going to test or V&V it. The V&V process must be integrated into the test process from the beginning.

Most tests already do V&V; they just don't realize and document them as such. A test developer needs to know if the ADS-enhanced test environment provides valid SUT data prior to using it. To accomplish this a series of tests that will reduce the risk of proceeding is developed. This series of tests, if documented, can become the V&V required prior to accreditation.

Tailor the V&V process. Unneeded V&V kills trees, costs time and money, and do nothing to reduce risk.

It is often impossible to fully validate an ADS-enhanced test environment. This is because the real world depicted by the environment is nonexistent or is not well documented. An example would be an enemy corps rear area. We can depict them doctrinally, but until they take to the field, we can not validate our depiction. Validation of an ADS-enhanced test environment is often a matter of getting a group of subject matter experts (SME) to agree that your test environment is a valid representation of reality without actually knowing what reality really is. Involve the accreditation authorities in selecting the SMEs and they will be more willing to accept their findings.

No complex system is ever used the way the designer thought it would be used. This will have an impact on V&V. V&V should be able to detect this deviate usage and determine what effect it will have on the system and the synthetic environment.

V&V should consider breakdowns or faults in the SUT. In our zeal to build perfect simulations, we often forget that everything breaks or malfunctions at some point in its usage. Often, reliability data or predictions are available to use in the simulations. V&V must determine that the simulations behave according to the reliability data or predictions.

V&V are never-ending processes. The tester always needs to know if the ADS-enhanced test environment is working correctly. For complex systems of systems environments, the tester must conduct V&V while collecting SUT data in order to prove post-test that valid SUT data have been collected. Additionally, the ADS-enhanced test environment may not exist in its actual test configuration until the first test event is conducted. Also, complex test environments may vary slightly from one test event to another and still be valid. Conducting some form of V&V during each test event will tell the tester that the test environment is valid.

5. Conclusion

This paper has described the VV&A activities that took place during the conduct of the End-To-End Test. The details and reports on the VV&A activity are contained on the JADS web site (http://www.jads.abq.com/) and contain a wealth of information on the conduct of VV&A for a distributed test. (After 1 March 2001 refer requests to HQ AFOTEC/HO, 8500 Gibson Blvd SE, Kirtland Air Force Base, New Mexico 87117-5558, or SAIC Technical Library, 2001 North Beauregard St. Suite 80, Alexandria, Virginia 22311.)

In addition, some of the lessons learned during the conduct of this test have been presented. The two most important lessons learned were that V&V are affordable if performed in conjunction with test design, integration, and functionality testing and that V&V reduce risk for the tester. If done wisely, V&V can provide a benefit to the tester, as opposed to being an onerous task required by regulation.

Author Biography

GARY J. MARCHAND is the technical lead for the End-To-End Test of the Joint Advanced Distributed Simulation Joint Test Force. He retired from the U.S. Army in 1993 after having been the deputy director and senior military analyst at the U.S. Army Training and Doctrine Command Analysis Command, White Sands Missile Range (TRAC-WSMR). He is currently employed as a senior analyst by SAIC.